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# AN INVESTIGATION OF A STRAUSS TRUNNION BASCULE BRIDGE

BY

REUBEN LAWRENCE SANDBERG

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THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

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COLLEGE OF ENGINEERING

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May 24, 1912

This is to certify that the thesis of REUBEN LAWRENCE SANDBERG entitled AN INVESTIGATION OF A STRAUSS TRUNNION BASCULE BRIDGE was prepared under my personal supervision; and I recommend that it be approved as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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# An Investigation of a Strauss Trunnion Bascule Bridge.

## Introduction.

The bascule bridge is the ancient moat bridge of feudal times reduced to modern practice. The oldest type of bascule is the fixed counterweight trunnion bridge in which the bridge revolves on a horizontal axis, and has a fixed counterweight on the short arm.

The Strauss trunnion bascule bridge is the logical development of the fixed trunnion bridge. The heel trunnion design is the latest type and has readily obtained recognition as the most economical design of bascule so far developed. In the heel trunnion type, the main trunnions are at the point of intersection of the bottom chord and the end post of the truss. The counterweight is separately mounted on trunnions supported on the counterweight tower. The Trusses of the moving leaf are pin connected to the counterweight trusses by means of links.

It is the purpose in this thesis to investigate this last

type of bridge, and the author has selected, through the courtesy of the Strauss Bascule Bridge Company Chicago, a through truss heel trunnion bascule bridge built over the Hackensack River, for the Erie Railroad Company, New York Division, at Hackensack New Jersey.

The specifications used are as follows; American Railway Engineering and Maintenance of Way Associations General Specifications for Steel Railroad Bridges 1906" supplemented by the Strauss Bascule Bridge Company's Specifications for this bridge.

# Chapter I Assumptions and Special Features

The assumed conditions, as stated in the following paragraphs, are those used by the Strauss Bascule Bridge Company in their design and are self explanatory.

The conditions are as follows:—

Relative to the D.L. pier reactions in a Strauss Trunnion Bascule Bridge (Heel Trunnion Type) the following points should be noted:

Whereas the moving leaf is at all times perfectly balanced there is no D.L. reaction at the front end.

The weight of the entire structure is therefore carried by the two tower piers

Disregarding for the sake of simplicity the weight of the counterweight link and the operating strut the reactions are due to:

1. The weight of the tower.
2. The weight of the moving leaf
3. The weight of the counterweight including trusses and bracing.

(1) The reactions due to the weight of the tower are vertical and constant.

(2&3) The moving leaf and the counterweight are supported

on the tower as on a carriage; they do not rest directly on the pier and if the tower is properly designed it takes care of the horizontal forces the horizontal component of the main trunnion reaction neutralizing the horizontal component of the counterweight trunnion reaction through the tower.

It follows that the pier reactions due to the weight of the moving leaf and the counterweight are vertical. Furthermore they are constant during the opening or closing of the bridge.

Owing to the fact that the four pins, main trunnion, counterweight trunnion and first and second link pins are located in the corners of a parallelogram, the angular movements of the moving leaf and the counterweight are the same, and, as the weight of the moving leaf is as much smaller than that of the counterweight as the lever arm of the latter is smaller than that of the former, it follows that the center of gravity of the system as a whole is not disturbed during the operation of the bridge, and therefore the pier reactions cannot vary.

This proved, it can be seen that the D.L. reaction on the main trunnion pier, disregarding the reaction due to the weight of the tower, is equal to the weight of the moving leaf and the D.L. reaction on the counterweight trunnion pier equal to the weight of the counterweight.

If namely, the bridge is opened to such an angle, about

90 degrees) that the center of gravity of the moving leaf falls directly over the main trunnion, then at the same time the center of gravity of the counterweight falls directly below the counterweight trunnion; the trunnion reactions have no horizontal components and it becomes evident that of the two piers the one carries the moving leaf and the other the counterweight.

Conclusion:-

In a Strauss Trunnion Bascule Bridge (Steel Trunnion Type) the D.L. pier reactions are vertical and constant.

(a) The D.L. reaction on the rest pier is zero.

(b) The D.L. reaction on the main trunnion pier is equal to the weight of the moving leaf plus part of the tower.

(c) The D.L. reaction on the counterweight trunnion pier is equal to the weight of the counterweight plus part of the tower.

Note:

In the above the counterweight means the concrete counterweight together with counterweight trusses, bracing, etc., and the center of gravity of the counterweight means the center of gravity of this composite body.

Relative to the reaction on the main trunnion of a Strauss Trunnion Bascule Bridge (Steel Trunnion Type) the following points should be noted:

Whereas the moving leaf is at all times perfectly balanced there is no D.L. reaction at the point end. The moving leaf is therefore subject to three outside forces only,

viz:

1. The weight of the moving leaf, which is a vertical force passing through the center of gravity of the moving leaf.

2. The link stress (link pin reaction) which passes through the second link pin and which coincides in direction with the counterweight link, since this is pin connected at both ends and would not be in equilibrium under any other condition.

3 The main trunnion reaction. Since the bridge is balanced this third force must pass through the point of intersection of the two others.

This point of intersection falls near the center of the span and somewhat below the bottom chord and the main trunnion reaction is therefore a force which passes through the trunnion and is directed towards the point of intersection (reaction) while the moving leaf butts against the trunnion, which is keyed to the tower in a direction which is inclined slightly downward and towards the tower (action).

It follows that according to the design the base (or body) of the main trunnion bearing which is riveted to the heel end of the bascule truss will always bear against the trunnion which is keyed to the tower truss and that the cap on this bearing might therefore be omitted if it were not for practical reasons (lubrication etc.

This also is shown by analyzing the stress in truss members.

The D.L. stresses in the four members intersecting at the hip joint (2nd link pm), including the end post are all tension.

At the two members intersecting at the main trunnion the D.L. stress in the end post is tension as stated, while the D.L. stress in the bottom chord member is compression and the resultant of these two forces is a force inclined slightly upward and acting away from the moving leaf against the tower (action), which again produces a reaction from the tower, as described above.

The L.L. reaction on the trunnions and the L.L. stress in the truss members are in no way different from those in an ordinary truss. The thrust of a train (braking load) coming from the trunnion end of the bridge, however, will tend to push the moving leaf away from the trunnion (that is produce bearing on the cap of the trunnion bearing and tension in the cap bolts), but in all cases so far investigated this force has not been sufficient to overcome the D.L. "action" going in the opposite direction and it could in any event be properly cared for by making the cap sufficiently strong.

Specification additional to Cooper's General Specifications for Steel Railroad Bridges and Viaducts 1906 and covering features special to bascule bridges.

(a) Structural steel pins and cast steel for structural purposes (Trunnion bearings, etc.) –

Case 1: Bridge closed and subject to dead and live loads: Loads and unit stresses as for stationary structures, in accordance with Cooper's "General Specifications for Steel Railroad Bridges and Viaducts, 1906".

Case 2: Bridge moving:

Find the actual maximum stress in each member that will occur at any angle of opening during the movement of the bridge and apply allowable unit stresses equal to $\frac{5}{6}$ of the dead load unit stresses for stationary structures. Neglect reversal of stress as this takes place slowly.

Wind load: 15 lbs. per square foot of entire surface of moving leaf figured center to center of trusses.

Journal bearing on trunnions under motion:

1700 lbs. per square inch.

(b) Operating Machinery –

Figure strength of operating machinery for a wind load of 5 lbs. per square foot as above, using the following

Unit stresses:

| | | |
|---|---|---|
| Slow speed shafting | 16,000 | lbs. per sq. inch. |
| High speed shafting | 12500 | " " " |
| Slow speed gears | 17,500 | " " " " |
| Medium speed gears | 12,500 | " " " " |
| High speed gears | 9,000 | " " " " |

(L) Motors:

Figure motors strong enough to operate the bridge against a wind pressure of $2\frac{1}{2}$ lbs. per square foot of moving load as above, in $1\frac{1}{2}$ minutes and also sufficient to operate bridge against a wind pressure of 10 lbs. per square foot.

STRAUSS TRUNNION BASCULE BRIDGE

OVER HACKENSACK RIVER
FOR ERIE RAILROAD CO.

THE STRAUSS BASCULE BRIDGE CO.
CHICAGO

STRAUSS TRUNNION BASCULE BRIDGE

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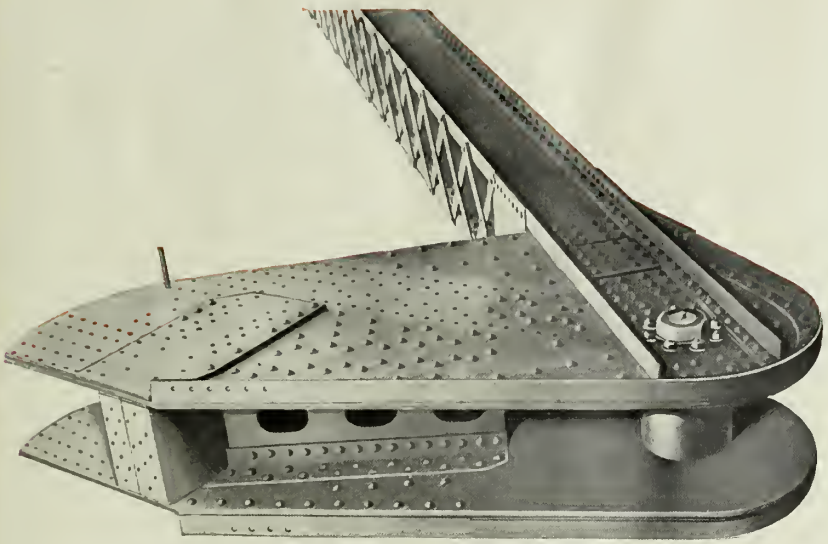
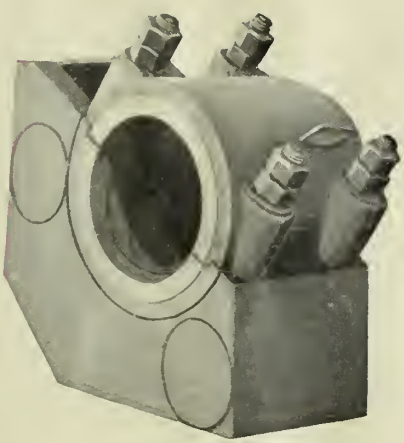
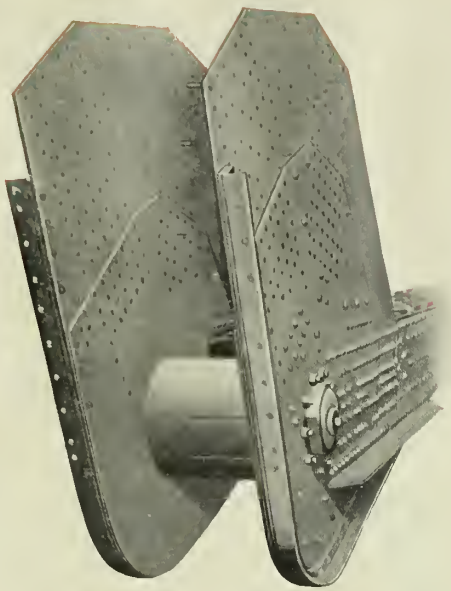
CHICAGO



MAIN TRUNNION



MAIN TRUNNION BEARING



COUNTERWEIGHT TRUNNION

COUNTERWEIGHT TRUNNION BEARING

# Chapter II Computation of Weight.

In order to determine the dead load stresses in the bridge, the actual weight of the complete structure was computed. A set of drawings furnished by the Strauss Bascule Bridge Company was used in estimating the weight of the material. The main members and details at panel points of the truss were billed separately three per cent being added for rivets in the members and five per cent for rivets at the panel points. The weight of the bracing between the trusses and the main members of the truss was distributed equally between their respective panel points in the truss. The operating machinery is carried at point nine of the bascule truss. The weight of the gears in the operating machinery were computed on the following formula:-

$w = k n b p^2$ (Taken from Unwin's Hand Book on Machine Design)

$w$ = weight in pounds

$k$ = 0.38 for spur gears

$k$ = 0.325 for bevel gears

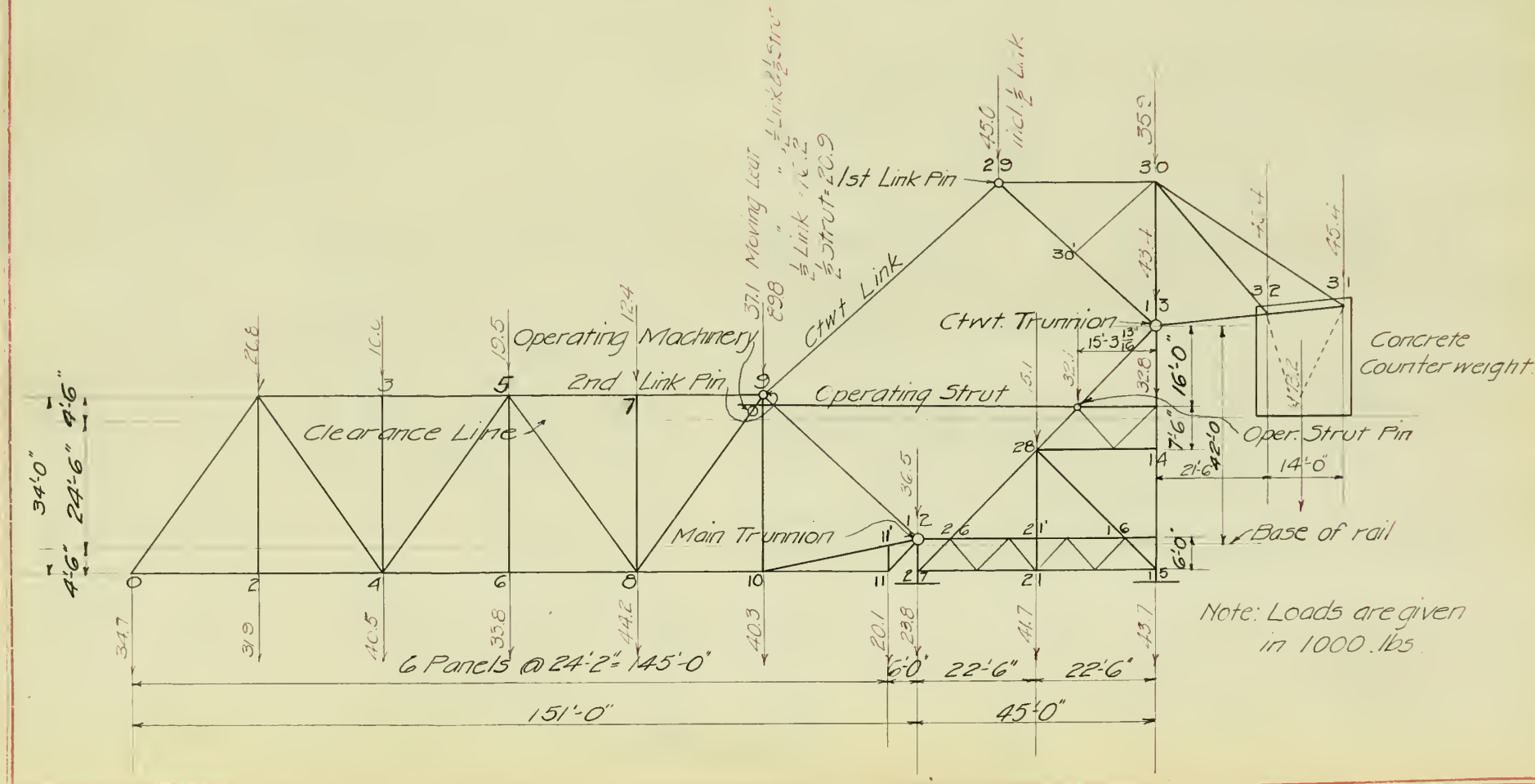
$n$ = number of teeth

$b$ = breath

$p$ = circular pitch

The actual volume of the cast steel bearings, pins and shafting were used in obtaining their weight.

# DIAGRAM OF BRIDGE
# SHOWING
# DEAD PANEL LOADING.



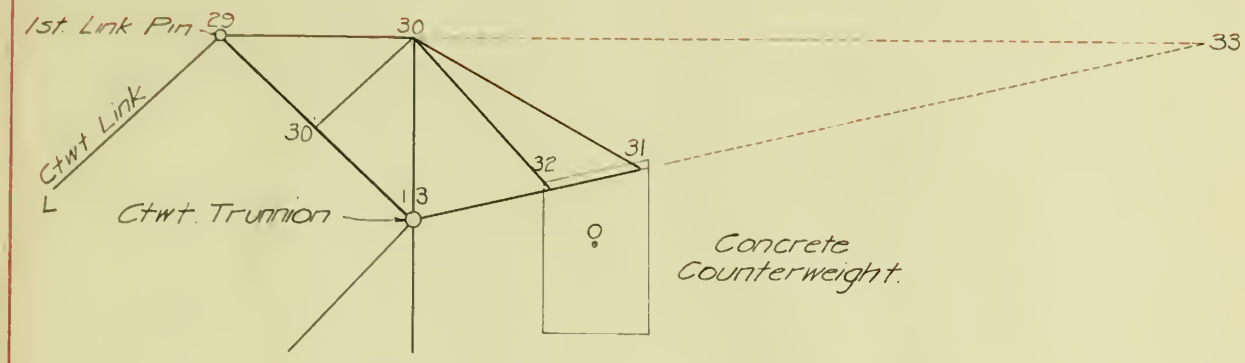

(15)

## Chapter III. Computation of Stresses.

The stresses in this bridge are due to the dead load, live load impact and wind. The dead load stresses in the moving leaf were figured under two conditions; bridge closed and bridge moving. The moving leaf was considered as a simple span in determining the live load stresses. The "Standard Specifications" were used in computing the impact stresses in the bascule truss for "bridge closed". The impact stresses in the bascule truss for "bridge moving" were figured as thirty-three and one-third per cent of the dead load stresses for "bridge moving".

The dead load stresses in the members of the tower truss were computed for the first condition only. A fixed set of rules were used in determining the maximum and minimum stresses in the counterweight truss. These rules were originally determined by the Strauss Bascule Bridge Company for a similar type of bridge.

The rules are as follows:




O = center of gravity of concrete counterweight.

29-30 Maximum tension when 0-13 is horizontal (bridge closed)

0 when link stress = 0 i.e. 0-13 is vertical.

Maximum compression when bridge is open.

29-13 Maximum compression when angle L-29-30 = 90°.

0 when link stress = 0

Maximum tension when bridge is open

30-3 Maximum tension when bridge is closed.

0 when 32-0 is vertical.

Maximum compression when bridge is open.

30-32 Maximum tension when 31-0 is horizontal

0 when 31-0 is vertical.

30-13 Maximum compression when 0-33 is horizontal.

13-32 Maximum compression when bridge is closed

0 when 0-30 is vertical

Maximum tension when bridge is open.

32-31 Maximum compression when bridge is closed

Maximum tension when bridge is open.

# STRESSES & SECTIONS IN MAIN TRUSS

| | Member | Case I Bridge Closed | | | | | | | Case II Br. Moving | | | Sections |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D.L | L.L. | | Impact | | Total | | D.L | Imp. 33 1/3% | Total | |
| | | | + | − | + | − | + | − | | | | |
| Top Chord | 0-1 | +42.4 | | +490.0 | | 254.0 | | 714.0 | +42.4 | +14.1 | +56.5 | 2 Webs 24"x 5/8". 2L 4"x4"x 9/16 Top. 1 Cov. pl. 32"x 3/8" 2L 4"x4"x 3/4", 2 Pls. 4"x 9/16 Bottom. |
| | 1-3-5 | +87.0 | | 440.0 | | 226.0 | | 605.0 | +87.0 | +29.0 | +116.0 | 2 Web pls 24"x 5/8", 4L 4"x4"x 11/16" |
| | 5-7-9 | +320.0 | | 580.0 | | 312.0 | | 668.0 | +320.0 | +106.5 | +426.5 | do do. |
| | 9-12 | -46.0 | | 600.0 | | 327.0 | | 973.0 | +44.0 | +14.6 | +59.6 | 2 Web pls 24"x 5/8". 2L 4"x4"x 5/8" Top, 1 Cov pl. 32"x 3/8" 2L 4"x4"x 3/4", 2 Pls 4"x 11/16" Bottom |
| | 11-12 | +29.7 | 204.0 | | 188.0 | | 422.0 | | +29.7 | +9.9 | +39.6 | 1 Pl. 19"x 1/2", 4L 6"x6"x 1/2" |
| Bot Chord | 0-2-4 | -24.7 | 288.0 | | 144.0 | | 405.0 | | -24.7 | -8.2 | -32.9 | 2 Web pls. 24"x 7/16", 4L 4"x4"x 7/16" |
| | 4-6-8 | -184.0 | 600.0 | | 306.0 | | 777.0 | | -184.0 | -61.2 | -245.2 | 2 " " 24"x 9/16", 4L 4"x4"x 9/16", 2 Pls 16"x 9/16" |
| | 8-10 | -496.0 | 441.1 | | 240.0 | | 334.0 | | -496.0 | -166.0 | -662.0 | 2 " " 24"x 9/16", 4L 4"x4"x 9/16", do. |
| | 10-12 | -580.0 | 451.0 | | 245.0 | | 291.0 | | -580.0 | -193.0 | -773.0 | 2 " " 24"x 3/4", 4L 4"x4"x 3/4", |
| Verticals | 1-2 | +31.9 | 186.0 | | 149.0 | | 367.0 | | +31.9 | +10.6 | +42.5 | 1 Pl. 20"x 1/2", 4L 7"x3 1/2"x 7/16" |
| | 3-4 | -10.0 | 0 | | 0 | | | 10.0 | -10.0 | -3.3 | -13.3 | 4L 7"x3 1/2"x 7/16" |
| | 5-6 | +33.7 | 186.0 | | 149.0 | | 369.0 | | +33.7 | +11.2 | +44.9 | 1 Pl. 20"x 1/2", 4L 7"x3 1/2"x 7/16" |
| | 7-8 | -12.4 | 0 | | 0 | | | 12.4 | -12.4 | -4.1 | -16.5 | 4L 7"x3 1/2"x 7/16" |
| | 9-10 | +142.6 | 186.0 | | 149.0 | | 478.0 | | +142.6 | +47.5 | +190.1 | 1 Pl. 20"x 3/4", 4L 7"x3 1/2"x 1/2" |
| | 11-11' | 0 | 0 | | 0 | | 0 | | 0 | 0 | 0 | 1 Pl 19"x 1/2", 4L 7"x3 1/2"x 1/2" |
| Diagonals | 1-4 | -106.5 | 315.0 | 29.3 | 177.0 | 23.8 | 492.0 | | -106.5 | -35.4 | -141.9 | 2 Webs 24"x 9/16", 4L 4"x 4"x 9/16" |
| | 4-5 | +168.0 | 86.0 | 198.0 | 62.0 | 125.0 | 316.0 | 32.3.0 | +168.0 | +56.0 | +220.4 | 2 " 24"x 7/16", 4L 4"x 4"x 7/16" |
| | 5-8 | -238.0 | 86.0 | 182.0 | 62.0 | 115.0 | | 535.0 | -238.0 | -79.2 | -317.2 | 2 " 24"x 5/8", 4L 4"x 4"x 1/2" |
| | 8-9 | +306.0 | 315.0 | 29.3 | 177.0 | 23.8 | 798.0 | | +306.0 | +102.0 | +408.0 | 2 " 24"x 9/16", 4L 4"x 4"x 5/8", 2 Pls 16"x 1/2" |
| | 10-11 | +21.0 | 144.1 | | 132.0 | | 297.0 | | +21.0 | +7.0 | +28.0 | 2 Pls. 16"x 7/16", 4L 4"x 4"x 3/8" |

Note: Plus (+) denotes tension. Minus (−) denotes compression
All stresses are given in 1000 lbs

(81)

# STRESSES & SECTIONS IN CTWT. TRUSS.

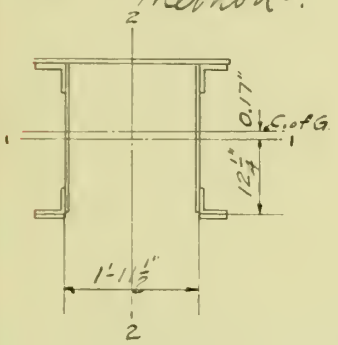
| Member | Max. Stress | | Imp. 33 1/3% | | Total | | Sections |
|---|---|---|---|---|---|---|---|
| | + | − | + | − | + | − | |
| 29-30 | 1290 | | 430 | | 1720 | | [ ] 2 Pls. 28"x 3/4", 2 Pls. 28"x 11/16", 4 L's 6"x4"x 11/16" |
| 29-13 | | 1070 | | 356 | | 1426 | [ ] do 2 Pls. 28"x 3/8" 4 L's 6"x4"x 1/2" |
| 30-31 | 915 | 955 | 305 | 318 | 1220 | 1273 | [ ] do. do. 4 L's 6"x4"x 11/16" |
| 30-32 | 1410 | | 470 | | 1880 | | [ ] 4 Pls. 28"x 11/16", 2 Pls. 20"x 3/8", 4 L's 6"x4"x 5/8" |
| 30-13 | | 1055 | | 351 | | 1406 | [ ] 2 Pls 28"x 3/4", 2 Pls. 28"x 3/8", 4 L's 6"x4"x 1/2" |
| 13-32 | 1230 | 1320 | 410 | 440 | 1640 | 1760 | [ ] do. 2 Pls. 28"x 3/4" do |
| 32-31 | 1838 | 963.0 | 610 | 321 | 2448 | 1284 | [ ] do. do do |
| 30-30' | 0 | 0 | 0 | 0 | 0 | 0 | ⌜⌝ 4 L's 6"x4"x 5/8" |
| | | | | | | | |
| | | | | | | | |

Note. Plus (+) denotes tension. Minus (−) denotes compression.
All stresses are in 1000 lbs.

# Chapter II Investigation.

It is the purpose in this chapter to investigate the main members of the bascule truss. The method of investigation is worked out in detail for a tension member and a compression member. A table follows giving the efficiencies of the other members of the truss.

## Method:




Member 0-1. $l = 41'-9"$

Dead load stress = +29,700 lbs.

Live " " = -490,000 "

Impact " = -254,000 "

Total " = -714,000 " (Direct stress).

$I_{1-1} = 7015.3 \text{ in}^4$. $I_{2-2} = 9748.9 \text{ in.}^4$

$r_{1-1} = 10.05$ $r_{2-2} = 11.87$. $\frac{l}{r_{1-1}} = 48$.

$p = 16000 - 70 \times 48 = 12,640$ lbs.

Gross area = 69.16 □".

Required area = 56.5 □" (for direct stress).

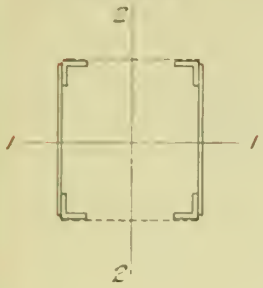
Efficiency = 82% (Does not take account of wind stress).

Total Actual Unit stress = 11,975 lbs. per sq. in.

Allowable unit stress = 10,300 " " " "

Efficiency = 86% (Takes account of wind stress.)

Member 0-2.




$l$ = 24-2"

Dead load stress = −24,700 lbs.

Live load stress = +288,000 " .

Impact " = −,44 000 .

Total " = +405,000

$I_{2-2}$ = 3190 in.⁴

Gross Area = 34.24 □". Net Area = 27.20 □".

Area reqd. = $\frac{405000}{16000}$ = 25.3 □".

Efficiency = 108 % (Does not take account of wind stress).

Actual Unit stress = $\frac{405,000}{27.2}$ = 5,400 lbs. per sq. in.

Unit stress due to wind = 16,000 " " " " .

Total unit stress = 17,000 " " " " " .

Efficiency = $\frac{16000}{17000}$ = 94 % (Takes account of wind stress).

## EFFICIENCIES OF MEMBERS IN MAIN TRUSS

| Member | Gross Area □" | Net Area □" | $\frac{l}{r}$ | Efficiency for Direct Stress | Eff. for Dir. Stress & Wind Stress | Remarks. |
|---|---|---|---|---|---|---|
| 0-1 | 60.7 | | 48 | 122 | 86 | Other end post same. |
| 1-3-5 | 50.1 | | 35 | 102 | 87 | |
| 5-7-9 | 50.1 | | 35 | 102 | 87 | |
| 0-2-4 | 34.2 | 27.2 | | 108 | 94 | |
| 4-6-8 | 61.8 | 50.6 | | 104 | 97 | |
| 9-10 | 35.0 | 29.5 | | 100 | | All other verticals similar. |
| 1-4 | 43.8 | 34.7 | | 113 | | |
| 4-5 | 34.2 | 27.2 | | 137 | | |
| 5-8 | 45.0 | | 62 | 98 | | |
| 8-9 | 61.5 | 49.9 | | 100 | | |
| 10-11 | 25.4 | 20.4 | | 113 | | |
| | | | | | | |
| | | | | | | |

# Chapter V Conclusion.

In looking over the diagram of the bascule bridge it will be seen that the distribution of the loading is fairly uniform. The stresses that were figured are a little larger than those originally designed for by the Strauss Bascule Bridge Company. The difference between the stresses is due to the approximate methods used by the designers in computing the dead load. The investigation was made only of the main members of the bascule truss. Very favorable efficiencies were computed, which can be found in the preceding chapter. All the efficiencies averaged about 100 per cent without taking account of the wind load. Taking account of the wind load reduced the efficiencies about 10 per cent. The results in general show that this bridge was well designed.

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